National Aeronautics and Space Administration

Age of the Universe: 6 Billion Years

COSMIC TIMES

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Size of the Universe: 4-8 Billion Light Years

Death of a Genius: Albert Einstein

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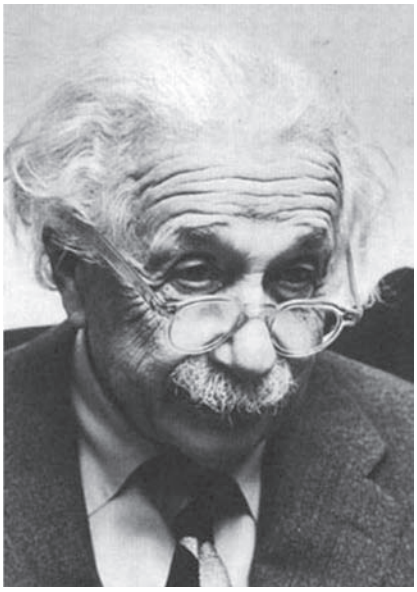

Albert Einstein in 1950.

The world has just lost its greatest scientific mind. Albert Einstein died in his sleep on April 18th from complications of a gall bladder infection. He was 76. There is no doubt that this rumpled, white-haired, pipe-smoking professor looked deeper into the nature of the Universe than any other man. In death he joins a select few – such as Newton, Copernicus, Archimedes and Pythagoras – as a giant in science whose genius changed the course of history.

The immediate outpouring of praise for the German-born scientist begins to reveal his place in history. President Eisenhower said "No other man contributed so much to the vast expansion of 20th century knowledge." Moshe Sharett, the Prime Minister of Israel, stated "The world has lost its foremost genius." There were even eulogies behind the Iron Curtain. Pravda, the official newspaper of the Soviet Union, described him as "A great transformer of natural science."

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'Yardsticks' in Neighbor Galaxy Double Universe's Size

Walter Baade, an astronomer at the California Institute of Technology, says the Universe is twice as large as we thought. He has used the giant 200-inch reflecting telescope at Mount Palomar to measure the scale of the Universe.

Baade's discovery hasn't come from simply reading mile markers in space. To properly determine the distance to stars and the scale of the Universe, he first had to discover that Nature has created more than one kind of measuring tool ("yardstick"). Until a few years ago, there was just one measuring tool known to astronomers, and it was being used incorrectly. Oddly enough, it took the wartime blackouts in Los Angeles to begin setting things straight. (These blackouts were periods of time at night when people had to turn off all lights or make certain all lights were blocked by heavy curtains to minimize the danger of night-time bombing or spying raids. During these times, light pollution was greatly reduced and astronomers could better study light from space.)

That first "yardstick" was discovered around the turn of the century. It is a type of pulsating, variable star called a Cepheid. Cepheid stars become very bright and then very dim (or pulsate) over a period of several days to several weeks. Henrietta S. Leavitt of the Harvard Observatory was studying the Magellanic Clouds, which are small galaxies outside of the Milky Way. Here she noticed that brighter Cepheids pulsed slower than dimmer Cepheids. This was interesting, because all the stars in the Magellanic Clouds are basically the same distance from Earth so it suggested that the rate at which those Cepheids were pulsing was a clue to their real brightness (or luminosity). By comparing how bright the stars really are, to how bright they look (their apparent magnitude), their distance could be calculated.

For example, if an astronomer sees a Cepheid in our own Milky Way galaxy that appears dim, he can observe how fast it pulsates to determine if the star is close or far away. He can use Miss Leavitt's brightness/pulsation relationship to do this. If the star pulsates rapidly, then the star re-

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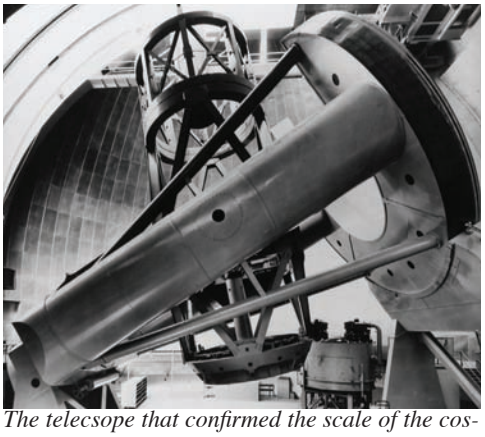
ally is dim and not far away. If the star pulsates slowly, then the star is actually bright, and only looks dim because it is very far away.

After Miss Leavitt completed her work, astronomer Solon Bailey discovered that the same relationship seemed to be true for Cepheids found in dense star clusters in our own Galaxy. Next, astronomer Harlow Shapley standardized the "yardstick" so he could measure the distance of fast-period and slow-period Cepheids both inside and outside these dense globular clusters in the Milky Way.



The telecsope that confirmed the scale of the cosmos: Mount Palomar's 200-inch Hale Telescope was completed in 1949.

"Thus a period-luminosity relation was established which covered the whole range of the Cepheid variation and which was accepted as the period-luminosity relation for the next 30 years," recalled Baade in a speech at a recent award ceremony of the Astronomical Society of the Pacific.

Unfortunately, Shapley's yardstick had flaws. In 1931, Doctor Edwin Hubble began studying the starlight from globular clusters in Andromeda, a galaxy near the Milky Way. For some reason those clusters were burning more dimly than the Cepheids here in the Milky Way. This mismatch meant either the globular clusters in Andromeda are basically different than those in our own Milky Way, or Andromeda must be further than originally calculated.

The solution to this mismatch came during the wartime blackouts of 1943 in California. Doctor Baade took advantage of the darkened skies and the power of the 100-inch Hooker telescope at the Mount Wilson Observatory near Los Angeles to re-examine Andromeda's globular clusters. Using special red-sensitive photographic plates Dr. Baade discovered two populations of stars:

- redder, fainter "Type II" stars in globular clusters near Andromeda's center and in its outlying halo (the same arrangement as in the Milky Way)
- bluer, brighter "Type I" variable stars located in open clusters in Andromeda's disk (outer spiral arms).

Dr. Baade realized that there must be two populations of Cepheids – Type I Cepheids more common in the disk of a galaxy and Type II Cepheids more common in the globular clusters.

According to Dr. Baade, Shapley did not realize Cepheids in globular clusters have a different period-luminosity relationship compared to Cepheids in open clusters. He made a major error when he treated them the same on his yardstick. This would be similar to treating a yardstick (Type I Cepheid) exactly the same as a meter stick (Type II Cepheid). They are very different measuring tools.

At Mount Palomar, Baade and his computer assistant Henrietta Swope recently confirmed that both types of Cepheids are very different types of stars. After recalibrating his measuring sticks, Dr. Baade startled his peers in 1952 at the Rome meeting of the International Astronomical Union by announcing that Andromeda was not 800,000 light-years away, as Hubble thought, but 1.8 million light-years distant. Likewise, with the two measuring sticks sorted out, the Universe we knew in 1929 to be one billion light-years wide has now doubled to two billion light-years across.

It's a Star! It's a Nova! It's Super-Nova!

There's more than one sort of "new" star in the heavens, say astronomers. The evidence has been building for decades that novae – those stars which light up suddenly to great brightness, then fade away – actually come in at least two distinct classes. On one hand there are ordinary novae and on the other there are truly Super-Novae.

The first clue that super-novae were lurking among the stars came 35 years ago. This clue was found by Edwin Hubble who died recently. Using his revolutionary method for measuring distances in space, he calculated that a nova observed in 1885 in the Andromeda Galaxy actually must have been about one hundred times more luminous (that is, brighter) than any nova recently observed in our own Milky Way Galaxy.

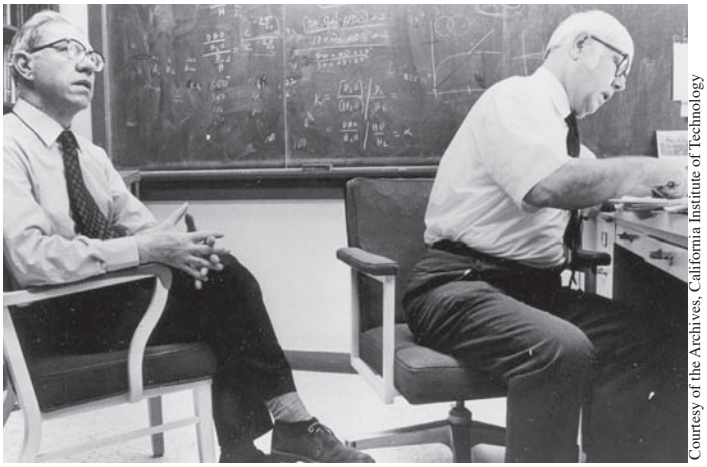
Fourteen years later in 1934, physicists Walter Baade and Fritz Zwicky used the term "super-nova" when they suggested these were not only far brighter than normal nova, but rare events in any given galaxy. The believed the most recent super-novae in our own galaxy were those recorded by astronomer Johannes Kepler in 1604, and another seen by Danish astronomer Tycho Brahe in 1572.

A new observation was added in 1941 by astronomer Rudolph Minkowski. He split the light from 14 distant super-novae into their component colors and found that nine of these spectrums contained no lines for hydrogen and five did. Super-novae without hydrogen lines are called Type I; super-novae with hydrogen lines are called Type II. The possible reason for this, speculates British astronomer Fred Hoyle, is that in the extreme violence of their "death", the giant stars that become supernovae might be capable of fusing hydrogen and helium to make heavier elements like carbon and iron. They are then not only Super, but actually Stars of Steel.

Origin of Everything: Hot Bang or Ageless Universe?

Has the Universe always existed, or does it have a beginning, middle and an end? It's difficult to imagine a deeper mystery than this. However, this topic was recently discussed at the meeting of the National Academy of Sciences in Pasadena, California.

The case for an ageless, steady-state Universe was presented at the conference by astrophysicists Jesse L. Greenstein and physicist William A. Fowler of the California Institute of Technology. The steady state theory says the Universe forever looks much like it does today; this "steady state" theory competes with the "evolutionary" theory of the Universe. The evolutionary theory claims an initial collection of hot particles exploded at the dawn of time. These particles formed all the Universe's hydrogen (and perhaps helium) in one gigantic event.



Courtesy of the Archives, California Institute of Technology

Fred Hoyle and William Fowler in Fowler's office in the W. K. Kellogg Lab at Caltech

Both theories explain – in entirely different ways – the fact that the Universe is expanding. This expansion was first detected in 1914, when American astronomer Vesto Melvin Slipher surveyed some galaxies and noticed the light from all of them was "red-shifted." All light travels in waves. In the spectrum of visible light, red light has the longest wavelength. If an object (such as a galaxy) is giving off light and the object is moving away, that motion lengthens the wavelengths, causing the light to "red–shift." It's similar to how the sound of a retreating locomotive drops in pitch as it passes by you.

In the steady-state theory the expansion comes from the continuous bubbling up of the element hydrogen, from empty space at a rate of one particle every cubic meter every 300,000 years or so. This hydrogen eventually gathers and condenses into stars. Through nuclear fusions in their cores, stars make all the heavier elements (e.g. carbon, oxygen, silicon, iron, copper, etc.) from this hydrogen. As stars age, die, and explode, they scatter the heavier elements around the galaxies. These heavier elements mix with hydrogen, and new stars form with rocky planets around them – like our own Solar System. As evidence of that process, Greenstein and Fowler referred to the heavy-element-making red giant stars which can be seen today in our own Galaxy.

An important point of the steady-state Universe is that it does change over time. Hoyle, the scientist who supports this theory, compares the deathless steady-state Universe to a river. It may appear unchanging, but there is plenty of movement and change under the surface. So, to borrow the old river saying, you can never step into the same Universe twice.

In contrast, there is the "evolutionary" theory of Russian-born American physicist George Gamow and his colleagues Ralph Alpher and Robert Herman. These scientists say the explosion and radioactive decay of a hot ball of neutrons at the birth of the Universe created all hydrogen and some helium. These elements formed as the blast expanded and cooled. The first stars were made of only this original hydrogen and helium. Those stars fused those original elements into new, heavier elements. These heavier elements were then scattered through the galaxies as the first stars died, and this led to the more complex mixtures of elements seen in stars now.

This evolutionary theory also explains why galaxies are moving away from each other: They are all still in flight from the power of the initial blast. Newton's laws of motion help to explain this [an object in motion will remain in motion unless a force acts on it …]. There may be other direct evidence of the blast as well. Alpher and Herman have predicted that some faint left-over heat from that initial explosion may still exist in the form of stretched-out light waves called "microwaves" just a few degrees above absolute zero. However, no one has yet figured out a way to detect these left-over microwaves.

More evidence for the evolutionary Universe comes from Edwin Hubble's 1929 measurements of the speed of galaxies beyond our own. Hubble found that the farther away a galaxy is, the faster it appears to be moving away. This is exactly what would be expected if there was an ancient blast that started it all and things have been moving away ever since.

The downside to an evolutionary Universe, of course, is that it doesn't end happily. There's no unlimited supply of hydrogen as in the steady state theory. In the evolutionary Universe, the Universe might expand forever and will eventually run out of hydrogen, the stars eventually burn out and the Universe cools down to a vast frozen graveyard of dead stars. Another possibility for the evolutionary Universe is that the gravity of all matter might eventually pull everything back together again in a gigantic collapse that rebounds, explodes, and starts the Universe all over – this is the endlessly exploding and collapsing Universe described by the late physicist Richard Tolman from CalTech.

Which theory is correct? Only more research with bigger and better telescopes will tell.

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Einstein's achievements are better known to his co-workers and students, who still work to understand, test and apply his theories. Examples of these are:

- his revolutionary re-thinking of light as not just waves but particles
- his theory of special relativity, which explains that nothing in the Universe can move faster than the speed of light.
- his most famous equation $E = mc^2$, which explains how matter can become energy, and energy can become matter
- his space-time bending theory of gravitation

Taken together, Einstein's ideas are the basis of all modern physics.

Non-scientists know Einstein was a genius, but don't really understand many of his theories. The average person knows that television and the hydrogen bomb are the results of his work, but doesn't understand how it is so. We are like the nurse at Einstein's deathbed who failed to understand the great man's final words that were spoken in German. She did not speak German. Most of us do not speak physics. Instead, we sense the importance of the man indirectly. We watch like children at a parade, as his life and his genius pass before us.

Hoyle Scoffs at "Big Bang" Universe Theory

British cosmologist Fred Hoyle has thrown down the gauntlet with regards to where and when all the Universe's elements were created. In a recent radio broadcast he criticized a competing theory, presented by Ukrainian-born American physicist George Gamow. He labeled Gamow's theory as a ridiculous "big bang."

Gamow's Evolutionary Theory of the Universe claims an initial stew of super-hot nuclear fusions of basic particles created all the hydrogen in the Universe in one explosive moment. The same blast caused space to expand. The ongoing expansion from that "big bang" is observed by astronomers today throughout cosmos.

Hoyle strongly disagrees with this theory. "It is an irrational process that cannot be described in scientific terms … [nor] challenged by an appeal to observation," he has written regarding Gamow's theory.

For one thing, the "big bang" requires something before the explosion. No one knows what that might be. If on the other hand, the Universe is eternal and stars are always being made and forever making heavier elements, as Hoyle suggests, there is no need for an initial explosion. Recent advances in nuclear physics seem to back Hoyle's "steady state" view, calling on the pressures and temperatures inside stars to manufacture all the heavy elements seen in the cosmos today.

Radio 'Ear' on the Universe Being Built

Jodrell Bank's Mark 1 radio telescope under construction.

Construction continues for what will be Earth's largest steerable radio antenna for studying radio waves from space. Objects too cool to produce visible light still produce radiowaves so this telescope will study those objects. The huge, 250-foot-wide metal dish of the Mark 1 radio telescope at Jodrell Bank in England is designed to be a fully adjustable. This will allow astronomers to explore the entire sky for radio transmissions – something they cannot do today. It will also be able to investigate the recently discovered 1420.4 Megahertz radio emissions thought to be coming from hydrogen gas at the center of the Milky Way.

The MK1 will replace the an older antenna at Jodrell Bank that is only slightly adjustable – it relies heavily on the spinning of Earth in its orbit to change its view of the heavens.

Despite that limitation, the eight-year-old parabolic aerial has led to some important discoveries which more than made the case for building the Mark 1, according to its designer Dr. Bernard Lovell of the University of Manchester. Among the most startling discoveries was that there are radio emissions coming from the Great Andromeda Nebula and that the brightest radio emitter in the night sky is from a little nebula in the constellation Cassiopeia.